Firms and Supply Chain Disruptions

Aaron Chatterji
Duke University and NBER
Fuqua School of Business
Durham, NC
ronnie@duke.edu

Yoko Shibuya
Duke University
Fuqua School of Business
Durham, NC
yoko.shibuya@duke.edu

September 23, 2024

Abstract

We develop a new measure of supply chain disruptions using shipping import data by calculating the difference between expected and actual arrival dates for over ten million import shipments to the U.S. from 2013 to the present. This index allows us to identify key patterns related to transportation disruptions during the COVID-19 pandemic. First, while the average shipment was delayed by eight days during the pandemic, significant heterogeneity exists across firms and industries. These variations in delays arise from operations at destination and origination ports, as well as the types of products imported. Second, firms that sourced from a wider variety of ports and countries experienced fewer delays. Additionally, firms with a higher percentage of intra-firm shipments encountered fewer shipping delays. Overall, our findings emphasize the need to understand how supply chain disruptions impact different firms and industries and how they respond, which is crucial for achieving national-level supply chain resilience.

1 Introduction

The growth of globalized supply chains is one of the most significant economic developments of the last century. These supply chains have been shown to improve firm productivity, lower consumer prices, and increase the variety of goods and services available (e.g., Alfaro and Chor, 2023). However, the supply chain disruptions during the COVID-19 pandemic raised concerns about the resilience of these systems in terms of both economic stability and national security. Bottlenecks in the supply of key inputs, such as aluminum, steel, lumber, and computer chips, led to shortages in 2021 and 2022, contributing to price increases in the U.S. Container ships faced significant delays, with dozens idling off the ports of Los Angeles and Long Beach, which hampered the delivery of imported products. Even everyday items like toilet paper were delayed by these disruptions[1].

The COVID-19 pandemic experience has sparked renewed interest in understanding the impact of supply chain disruptions and in developing resilience at both global and national levels to address future challenges. Despite significant attention to this topic, there remains no consensus on how to achieve optimal supply chain resilience. A key challenge in this discussion is our limited understanding of how supply chain disruptions affect different industries and firms. Most supply chains are shaped by private sector firms and market forces, so it is essential to explore how disruptions impact various firms and industries differently, as well as how each firm seeks to mitigate those effects.

In this paper, we introduce a novel metric for assessing supply chain disruptions and apply it to analyze the impact of the global pandemic on the private sector. Existing research has measured supply chain disruptions using fluctuations in shipping prices, surveys of purchasing managers (Benigno et al., 2022), port-level ship congestion (Bai et al., 2024), and the deterioration of supplier-buyer relationships (Smirnyagin and

[1] https://www.whitehouse.gov/cea/written-materials/2021/06/17/why-the-pandemic-has-disrupted-supply-chains/

Tsyvinski, 2022). In contrast, we utilize shipping import data to construct a measure of shipping delays at the shipment level, defined as the difference between expected and actual unloading times. By creating a comprehensive dataset that links firms, shipments, origin and destination ports, estimated arrival times, and actual unloading times, we gain valuable insights into transportation disruptions within supply chains.

To validate our measure, we examine its correlation with existing supply chain disruption indicators. Our measure shows a strong correlation over time with other disruption metrics at the aggregate level, although some discrepancies arise due to the differing nature of these measures. For example, disruption metrics based on supplier-buyer relationships reflect firms' decisions regarding the maintenance of those relationships, while our measure specifically focuses on shipping delays that are largely exogenous to importing firms. Additionally, other measures capture disruptions that occur at various stages of the supply chain, such as suppliers' financing or production issues, whereas our measure targets disruptions that happen during the shipment process between exporting and importing firms.

We present several stylized facts based on the new measure that helps us understand the impact of the COVID-19 pandemic on firms. First, we illustrate the baseline time series movement of the aggregate import shipping delay index, which indicates that the pre-pandemic average shipping delay of 1 to 2 days increased to 8 days during the pandemic. We then investigate the sources of these delays. Our variance decomposition reveals that most delays are primarily driven by slowdowns in operations at both origination and destination ports. Slowdowns at origination ports can be attributed to global port lockdowns during the pandemic, while delays at U.S. destination ports often stem from congestion. Additionally, since unloading an entire ocean vessel typically takes several days even under normal circumstances, the order of unloading matters for shipping delays. For instance, perishable and lightweight products may be unloaded faster than heavy, durable goods.

We next examine how shipping delays are distributed across firms and industries. Our findings reveal that the 8-day average delay during the pandemic conceals considerable heterogeneity—some firms and industries experienced much longer delays than others. The top quartile of firms, in terms of average shipping delay, faced delays greater than 12.77 days, while the bottom quartile experienced delays of only 4.61 days during the same period. Industries producing perishable goods encountered significantly shorter delays compared to heavy manufacturing and healthcare. Furthermore, we utilize industry input-output tables to explore how delays in supplier industries can lead to indirect delays in the focal industry. We find that the variation in total delays (both direct and indirect) is much greater than that of direct delays alone. Some industries that were not severely impacted by direct shipping delays can still be heavily affected by indirect delays due to their reliance on inputs from industries that were hit hard by shipping disruptions.

Interestingly, firms that utilize a wider variety of origination and destination ports and source from a larger number of countries experience fewer delays. This advantage arises from their ability to shift and reroute shipments from less efficient ports to more efficient ones. Additionally, firms with more integrated supply chains tend to experience fewer delays, even after controlling for the total number of shipments. We measure the degree of supply chain integration by calculating the share of import shipments made within the firm and find that those firms that conduct a higher percentage of their shipments via intra-firm trade face fewer delays. This may be attributed to their increased flexibility in shipping, such as the ability to choose ports more strategically when transactions occur within the firm.

Based on these findings, we discuss approaches to measuring supply chain resilience. We argue that while resilience is typically discussed at the national level, it is essential to develop firm-level disruption measures. This approach can help identify which firms and industries are most impacted by disruptions and how they respond to the shock

differently. Ultimately, a nation's resilience depends on the strength of its private sector supply chains.

The remainder of the paper is organized as follows. In Section 2, we provide a brief overview of the economics literature on supply chain disruptions. The construction of our measure is detailed in Section 3, followed by the presentation of several stylized facts in Section 4. Finally, we discuss the implications of our findings for future research and offer observations on measuring supply chain resilience in Section 5.

2 Literature Review

There is a long tradition of research in economics on global supply chains, as summarized by Baldwin and Freeman (2022). The populist backlash against globalization in many developed economies has led to increased attention to the costs and benefits of global supply chains. Moreover, the environmental sustainability of supply chains (Kim and Davis, 2016; Gopalakrishnan et al., 2021) and their resilience to natural disasters, such as earthquakes, has also emerged as a topic of interest (Boehm et al., 2019; Carvalho et al., 2021). The COVID-19 pandemic further accelerated academic interest in supply chains, as disruptions hindered commerce worldwide and impacted price levels and GDP (Baldwin et al., 2023; Schwellnus et al., 2023; Gordon and Clark, 2023).

In the United States, disruptions caused by the COVID-19 pandemic and heightened political tensions with China have led to policies aimed at boosting domestic manufacturing, increasing tariffs on imported goods, and creating supply chains that are more resilient to geopolitical shifts, natural disasters, and other shocks (Alfaro and Chor, 2023; Goldberg and Reed, 2023). The U.S. government recently released detailed supply chain reports and identified priority sectors for investment to facilitate the "reshoring" of manufacturing, particularly within the global value chains supporting the

digital economy and energy sectors (White House, 2021a).

Academic studies have explored the impact of these policies and highlighted the difficulties of defining resilience. Alfaro and Chor (2023) document that supply chains are already being rewired. Between 2017 and 2022, the U.S. reduced its import share from China, shifting to imports from Vietnam and Mexico. The authors call this the "great reallocation" away from China and document preliminary evidence of reshoring manufacturing in the U.S. Goldberg and Reed (2023) argue that globalization is slowing down in terms of trade measures, but not reversing. They also point out that the concept of resilience is poorly defined, which hinders the evaluation of most new supply chain policies.

Recent theoretical work has aimed to derive optimal supply chain policies, describing the conditions under which government policies should promote greater diversification of supplier countries (Grossman et al., 2023) and the determinants of socially optimal investment in supply chain resilience (Grossman et al., 2024). However, it has been difficult to test predictions about supply chains empirically due to the challenges in measuring supply chain disruptions in the first place, let alone resilience to shocks.

In the prior literature, scholars have measured supply chain disruptions using various sources, including newspaper articles (Burriel et al., 2023), corporate earnings calls (Wu, 2024), transportation price fluctuations (Benigno et al., 2022), port congestion data (Bai et al., 2024), and supplier-buyer relationships (Smirnyagin and Tsyvinski, 2022). However, these measures have several limitations when applied to studying their impact on firms.

First, while aggregated measures of supply chain disruptions—such as country- or port-level data—provide useful insights, the concepts of disruption and resilience fundamentally originate at the firm level. There can also be considerable heterogeneity among firms regarding the impact of supply chain disruptions on their operations.

Second, some measures of supply chain disruptions combine multiple disruption

sources, which can obscure important information about where disruptions originate. For instance, disruptions may arise from production delays, suppliers' financial issues, production problems, or transportation bottlenecks, each having different effects on firms, industries, and the overall economy. To fully understand supply chain resilience, it is essential to study each source of disruption individually.

Lastly, measures based on supplier-buyer relationships and transportation prices are influenced by firms' endogenous responses to supply chain disruptions. As a result, these measures may not be suitable for analyzing how exogenous shocks to supply chains impact firms. To address the gaps detailed above, we constructed a measure of import shipping delays that captures exogenous firm-level shipment disruptions.

Finally, an emerging literature has explored the impact of the COVID-19 pandemic specifically on firms' strategies, though typically without granular measures of supply chain disruptions. These studies have explored how firms shifted their sourcing strategies (Cajal-Grossi et al., 2023), substituted across key inputs (Khanna et al., 2022), and transitioned to domestic suppliers (Chacha et al., 2024) or different global suppliers (Heise, 2020) in response to the disruptions in supply chains during the pandemic.

3 Data and Construction of the Index

3.1 Data

The FactSet Shipping Data provides a comprehensive record of bill of lading (BoL) information, capturing detailed shipment-level records of goods traded across U.S. borders. This dataset includes over ten million shipments annually from nearly 200 U.S. ports, covering the period from 2013 to the present.

FactSet Shipping data focuses specifically on seaborne imports. As noted in Flaaen et al. (2023), maritime trade is the largest mode of transport by value, accounting for nearly half of U.S. import values in 2019. However, excluding non-maritime trade

can create gaps in coverage for some of the United States' major trading partners. For example, trade with Mexico and Canada—two of the U.S.'s largest trading partners—is primarily conducted via land-based transportation. Consequently, imports from these countries are largely omitted from our sample.

The data consist of BoL from U.S. Customs and Border Protection (CBP), which are publicly accessible under the Freedom of Information Act of 1966. A BoL is a legal document that records the transportation of a shipment from its origin to its final destination. Each BoL includes detailed information such as the names and addresses of the shipper (exporter) and consignee (importer), a description of the goods, the vessel name, the carrier company, ports of loading (origin) and unloading (destination), weight, quantity, and container information. Additionally, the carrier company provides the expected date of unloading, while the destination port authority records the actual date of unloading. This information on expected and actual unloading dates will be used to measure shipping delays, which will be explained in detail in Section 3.2.

Table 1 presents the number of data entries by variable for the years 2019 and 2022, which are the primary years for our analysis. Each year, the FactSet Shipping Data comprises over 16 million import shipments, covering approximately 200 U.S. destination ports and more than 1,000 origination ports worldwide. The dataset includes around 100,000 U.S. consignees who import products and over 100,000 shippers who export products to these consignees.

The table shows a steady or gradually increasing in the number of shipments and ports covered in the data, while we observe gradual decline in the number of consignees and shippers. The gradual decline reflects redaction activities by firms. Companies can request that the U.S. CBP redact their identity from the shipper or consignee fields, which means their identities are not visible in the FactSet data (for a more detailed explanation of these redaction activities, see Appendix A.1). For analyses requiring shipper or consignee identities, we exclude shipments with unidentified entities.

Table 1: Number of Entries by Variable

	Shipment	Dest. Port	Orig. Port	Consignee	Shipper
2019	16,014,941	199	1161	101,394	123,272
2020	16,559,824	200	1134	98,831	121,039
2021	18,007,129	202	1107	99,901	119,057
2022	18,687,191	204	1119	70,589	85,612

Source: FactSet Shipping Data and authors' calculations.

Table 2 displays the average number of shipments per year for ports, consignees, and shippers. There is significant variability in the number of shipments across ports. The median destination port handles 43 shipments per year, while the largest destination ports manage up to 3.6 million shipments annually. Similarly, the median origination port processes 48 shipments per year, whereas the largest origination ports handle up to 2.6 million shipments annually. The top three destination ports with the highest number of shipments from 2019 to 2022 are port of Los Angeles, New York/Newark, and Long Beach, and the top three origination ports during the same period are the Port of Ningbo, Shanghai, and Yantian in China (see Appendix A.1 for more detail).

There is also considerable variability in the number of shipments received by consignees and sent by shippers. The median consignee receives 5 shipments per year, while the largest consignee receives over 100,000 shipments annually. The median shipper sends 6 shipments per year, while the largest shipper sends 35,000 shipments to the U.S. every year.

3.2 Import Shipping Delay (ISD) Index

We calculate the Import Shipping Delay (ISD) Index for each shipment by taking the difference between the *actual* and *estimated* unloading dates in the FactSet Shipping Data. The estimated unloading date is provided by the carrier on the BoL before the shipment departs from the origin port. The actual unloading date is recorded by the destination port agent on the BoL as the date the cargo is unloaded. For instance,

Table 2: Number of Shipments per Year

# of annual shipments per...	Mean	Std	Min	25%	50%	75%	Max
Destination port	86048.5	401039.5	1	5	43	945	3,602,330
Origination port	15294.4	117363.7	1	7	48	508	2,614,956
Consignee (importer)	67.4	759.4	1	2	5	23	116,618
Shipper (exporter)	52.3	409.9	1	2	6	23	35,541

Source: FactSet Shipping Data and authors' calculations.
Note: The count of shipments per consignee and per shipper excludes any shipments where the consignee or shipper is unidentified.

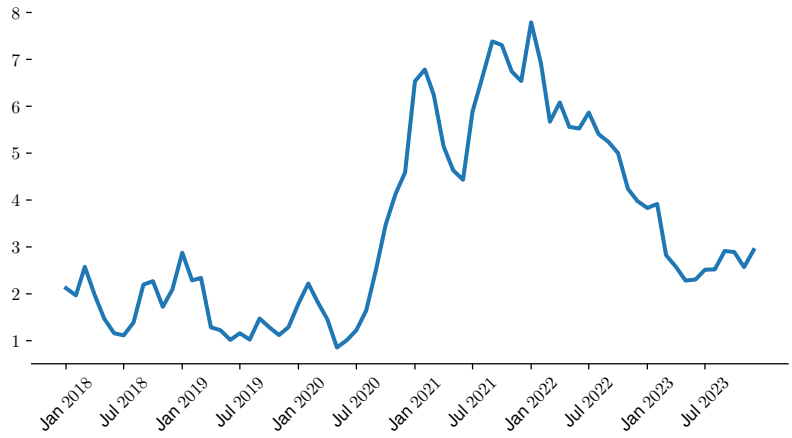
if a shipment was expected to unload on January 21, 2024, but actually unloaded on January 27, 2024, the ISD for that shipment would be 6 days. By design, the ISD Index can be negative, which indicates that the cargo was unloaded earlier than the carrier had estimated.

The ISD Index reflects unexpected delays in import shipments for each consignee. When carriers provide the expected unloading date at the origin port, consignees use this information to plan their production and logistics schedules accordingly. Therefore, any delay indicated by the ISD highlights unforeseen disruptions in the shipping process that are likely exogenous to the consignee's operations.

Supply chain disruptions can arise from various sources, and our index specifically measures the impact of unexpected import shipping delays on buyer firms. Other potential disruptions include suppliers' inability to secure financing (credit shock, Agca et al. 2022), production halts due to quarantine measures (production shock, Baqaee and Farhi 2020), and trade restrictions like tariffs between countries (price shock, Fajgelbaum et al. 2024). It's crucial to employ different measures for the different sources of disruptions, as each source affects buyer firms in distinct ways.

In theory, we can calculate the ISD for each shipment that has both expected and actual arrival dates recorded. However, errors in the ISD index can occur due to typos in these dates. While there is no systematic method for detecting such errors, some anomalies are apparent; for instance, some actual arrival dates appear more than 365

Figure 1: Timeseries of the ISD Index (Days)



Source: FactSet Shipping Data and authors' calculations.
Note: Monthly average of the ISD index. The y-axis represents the number of days, while the x-axis represents the months.

days later than estimated dates, which may indicate errors in the year. To mitigate these issues, we exclude outliers from the ISD Index that fall outside the central 99% of the distribution. After making this adjustment, the minimum ISD Index is -10 days, while the maximum is 29 days.

Figure 1 shows the monthly average of the ISD index across shipments. Before mid-2020, the index remained stable, averaging around 1-2 days, which indicates that, on average, each shipment only delayed for about a day or two. There was a sharp increase afterward, peaking at almost 8 days between January 2021 and January 2022, reflecting significant supply chain disruptions caused by the COVID-19 pandemic. The index stayed elevated until mid-2022, then started to decline, eventually returning to approximately 3 days by the end of 2023.

The impact of such an increase in shipping delay is substantial for recipient companies. According to Foroohar (2024), 57% of industries in the U.S. would require six months to return to normal capacity following even a single week of transport disruption. Therefore, an average delay of 8 days during the COVID-19 pandemic can severely disrupt operations, leading to extended recovery periods and significant

operational challenges.

Since the ISD is the difference between expected and actual unloading dates, with the expected date provided by carriers, one might be concerned that carriers' expectations regarding unloading dates shift as more information about transportation disruptions becomes available during the COVID-19 pandemic. As shipping delays became more apparent, carriers likely adjusted their expectations and revised the anticipated unloading dates to reflect these potential delays. This adjustment is beneficial for our measure, as it reflects the delays consignees experience relative to carriers' anticipated unloading dates. When carriers foresee longer delays, consignees adapt their production and logistics planning accordingly. Therefore, changes in carriers' expectations enhance the relevance of our measurement rather than detract from it.

Appendix A.2 compares the ISD index with other supply chain disruption indices from the literature, specifically the Global Supply Chain Pressure Index by the Federal Reserve Bank of New York and the Supply Disruptions Index compiled by Smirnyagin and Tsyvinski (2022). Two key points emerge from this comparison. First, our ISD index shows a parallel trend with these other indices, indicating that it effectively captures the overall pattern of supply chain disruptions. Second, the differences among these indices affect how supply chain disruptions are measured. Some capture disruptions at the supplier production stage, while our index concentrates exclusively on shipping disruptions. Additionally, our index measures shipping disruptions that are largely exogenous to consignees, whereas other indices may reflect decisions made by firms.

Table 3 shows the distribution of the ISD index across shipments between 2019 and 2022. Two key observations emerge. First, there was a significant upward shift in the distribution of the ISD index during the pandemic. The median shipment experienced a 6-day delay in Q1 2021, compared to just a 2-day delay in Q1 2019.

Second, despite the pandemic, there remained considerable variability in shipping

delays across shipments. In Q1 2021, for instance, the average shipment delay was 6.50 days. During this period, 25% of shipments experienced delays of less than two days, while another 25% faced delays exceeding 13 days. The variability in shipment delays became even more pronounced in Q1 2022, where the average delay was 6.83 days with a standard deviation of 7.21 days, indicating a broader range of delays.

Table 3: Distribution of the ISD Index across Shipments Over Time

	Count	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
Q1 2019	3,721,132	2.51	3.50	-10.0	0.0	2.0	4.0	29.0
Q1 2020	3,437,964	1.93	3.12	-10.0	0.0	1.0	3.0	29.0
Q1 2021	4,581,643	6.50	5.84	-10.0	2.0	6.0	11.0	29.0
Q1 2022	4,029,587	6.83	7.21	-10.0	1.0	5.0	13.0	29.0

Source: FactSet Shipping Data and authors' calculations.

4 Results

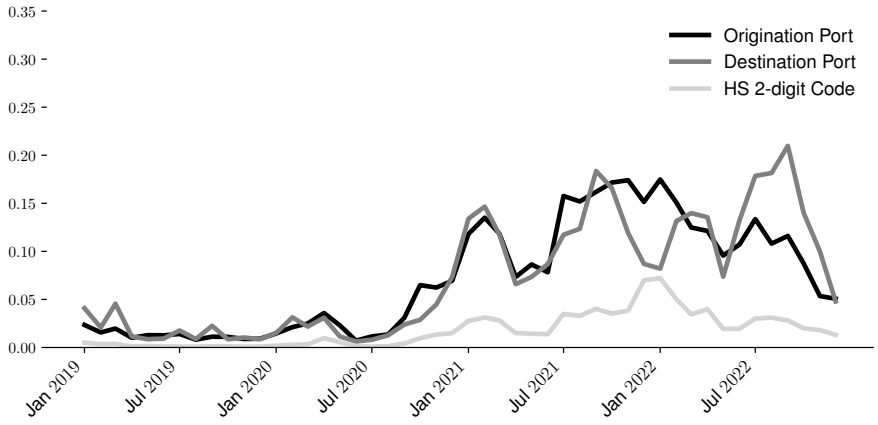
This section presents five key facts about import shipping delays in the U.S. during the COVID-19 pandemic. While these facts are descriptive and not intended to imply causation, they provide valuable insights into the nature of these delays and their varying impacts on different firms and industries.

Fact 1: Shipping Delays Largely Originate from Port Operations. The first fact highlights the origins of import shipping delays. Our analysis shows that between January 2021 and December 2022, the main factors contributing to the variance in import shipping delays in the U.S. were delays at both destination and origination ports, each responsible for over 15% of the variance in the ISD index. Additionally, the product category of the shipments emerged as another significant factor influencing this variance.

The contribution of each factor, reported in Figure A.1, fluctuates over time. The

figure presents a variance decomposition of the ISD Index, breaking it down into variances explained by delays at origination ports, destination ports, and product categories defined at the 2-digit HS code level. Before mid-2020, when shipping delays were less severe, these factors contributed minimally to delays, suggesting that they were largely due to random fluctuations. However, post-mid-2020, contributions from both origination and destination ports increased significantly, each accounting for nearly 15% to 20% of the variance in shipping delays. Additionally, the impact of product category codes grew towards 2022, eventually contributing over 5% of the variance. It is important to note that the variance attributed to origination and destination ports may also reflect differences in the types of products handled, as some ports specialize in specific categories.

Figure 2: Variance Decomposition of the ISD Index



Source: FactSet Shipping Data and authors' calculations.
Note: The figure shows the variance decomposition of the monthly averages of the ISD Index into destination port, origination port, and HS 2-digit level product category. The y-axis represents the share of variance attributed to each factor. The x-axis denotes the months.

This analysis leads us to identify three distinct stages at which shipping delays can occur. The first stage encompasses delays that occur after the carrier has provided the expected unloading date on the BoL but before the ship actually departs from the origin port. Such delays might be caused by factors like port shutdowns around the world during the pandemic, which slow down operations at the origination port. For

instance, in May and June 2021, Yantian Port in China implemented strict COVID-19 control measures following the detection of a few cases among port workers, resulting in a sharp increase in the ISD index for shipments originating from Yantian Port (see Appendix A.3.1).

The second stage covers delays occurring between the ship's departure from the origin port and its arrival at the destination port. These delays can be attributed to unexpected natural events like storms, accidents, or changes in ocean currents, as well as unexpected congestion at U.S. destination ports.[2] For example, during the pandemic, the Port of Los Angeles and the neighboring Port of Long Beach experienced significant congestion, leading to longer average shipping delays for shipments arriving at these ports compared to other major ports on the East Coast (see Appendix A.3.1).

The final stage involves delays during the unloading process at the destination port. This complex operation can be affected by various issues, with major causes including operational inefficiencies and schedule changes. Additionally, the order in which cargo is unloaded can impact delays for each shipment, as port authorities follow a specific sequence when unloading containers, resulting in varying unloading times for containers on the same ship.[3]

Fact 2: Delays Are Unevenly Distributed Across Firms. In the previous section, we observed that shipping delays varied significantly across different shipments. Fact 2 indicates that these delays were also unevenly distributed among consignees. Table 4 summarises the distribution of the average ISD index across consignees. The first three rows of the table present the distribution of the ISD index for Q1 2022, for all consignees, and consignees in the top and bottom quartiles in terms of the number of shipments. On average, consignees experienced 8.58 days of delay for their shipments,

[2] Bai et al. (2024) highlights that port congestion can lead to significant delays in product imports.

[3] Actual unloading times vary across shipments. According to Flexport, it generally takes one to three days to unload entire ocean vessels. Additionally, the time container ships spent waiting to be unloaded during the pandemic significantly exceeded pre-pandemic averages (Rosalsky 2021).

with 25% of firms facing delays exceeding 12.77 days.

Additionally, while one might expect that firms with greater negotiation power at the destination port—such as those with higher shipment volumes—could leverage their influence for faster unloading, our findings do not support this hypothesis. The extent of shipping delays does not significantly differ between firms with larger shipment volumes and those with fewer. On average, consignees in the top quartile of quarterly shipments experienced delays of 8.12 days, whereas those in the bottom quartile faced delays averaging 8.78 days.

Similarly, when we aggregate shipments to the ultimate parents of consignees using corporate tree information from FactSet, we still observe substantial variation in delays among these ultimate parents (see the last three rows of Table 4). There is a slight difference in average shipping delays between ultimate parents with higher and lower shipment volumes. Ultimate parents in the top quartile of shipments experienced an average delay of 8.22 days, while those in the bottom quartile faced delays averaging 9.01 days.

These variations in delays across importing companies are likely influenced by several factors, including the differential use of origin and destination ports and types of products they import, which Fact 1 identifies as major contributors to delay variation. Other contributing factors include the timing of shipments within the quarter and the types of products imported. While the difference in negotiation power of importing companies over destination ports may contribute to the variation, it appears to be a minor factor compared to the others.

Fact 3: Delays Are Unevenly Distributed Across Industries. Fact 3 illustrates that the impact of import shipping delays varies significantly across different industries. Building on Facts 1 and 2, which highlight the uneven effects of shipping delays on consignees during the COVID-19 pandemic—likely due to variations in the use of origin and destination ports—our dataset reveals that these disparities persist

Table 4: ISD Index across Consignees and their Ultimate Parents (Q1 2022)

Consignee	**Count**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
All	54474	8.584	5.412	-10.0	4.615	8.80	12.777	29.0
Top quartile (> 7 shipments)	13974	8.126	3.732	-4.676	5.608	8.392	10.800	29.0
Bottom quartile (= 1 shipment)	16402	8.788	6.913	-10.0	3.0	9.0	15.0	29.0
Consignee' ultimate parent	**Count**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
All	44382	8.749	5.366	-10.0	5.0	9.0	13.0	29.0
Top quartile (> 8 shipments)	11204	8.222	3.623	-4.428	5.857	8.474	10.786	29.0
Bottom quartile (= 1 shipment)	13129	9.011	6.940	-10.0	3.0	10.0	15.0	29.0

Source: FactSet Shipping Data and authors' calculations.
Note: The calculation of the average ISD index per consignee excludes any shipments where the consignee is unidentified.

when shipments are aggregated to industry. We use firm-SIC industry codes provided by FactSet to categorize consignees by industry.[4]

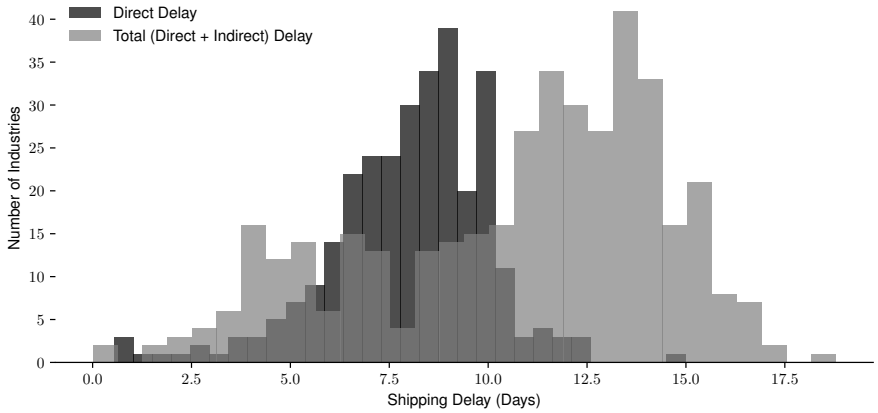
To evaluate industry-level shipping delays, we employ two methods. The first method, termed *direct* shipping delays, involves averaging the import shipping delays experienced by firms within each industry. The second method accounts for *indirect* shipping delays arising from supplier industries due to input-output relationships. We use the 2022 direct input requirement matrix from the Bureau of Economic Analysis to quantify the delays caused by disruptions in these supplier industries. We then combine these indirect delays with direct shipping delays, referring to the resulting measure as *total* shipping delays.

Figure 3 illustrates the distribution of direct and total shipping delays across industries for Q1 2022. The dark gray histogram represents direct delays, while the light gray histogram shows total delays, calculated as the sum of direct and indirect delays. We observe some variation in direct shipping delays across industries, with the median industry experiencing an average direct delay of 8.31 days in Q1 2022 and a standard deviation of 2.03 days.

[4]Among all shipments recorded in the FactSet Shipping data with consignee IDs, 98% have assigned primary SIC codes. We exclude observations without assigned primary SIC codes from the industry-level analysis.

The variation becomes even more pronounced when considering total shipping delays. Industries at the median faced average total delays of 11.65 days in Q1 2022, with a standard deviation of 3.74 days. This increased variance in total shipping delays is largely due to indirect delays from supplier industries. If an industry relies heavily on inputs from other industries that are significantly affected by direct shipping delays, it can experience substantial total delays, even if the focal industry itself does not encounter significant direct delays.

Figure 3: Average Shipping Delays across Industries in Q1 2022



Source: FactSet Shipping Data and authors' calculations.

The top panel of Table 5 lists the five industries with the smallest and largest average direct shipping delays for Q1 2022. Industries with the smallest direct delays include those related to farming, mills, and wells, likely due to their perishable input products which can be unloaded more quickly at destination ports. In contrast, industries with the largest direct shipping delays include auto and electronics manufacturing, healthcare products, and postal services.

The bottom panel of Table 5 presents the five industries with the smallest and largest average total shipping delays, including both direct and indirect delays for Q1 2022. The inclusion of indirect delays through supplier industries alters the rankings. Industries with the smallest total delays include government, gambling, education, and

newspaper publishing. These industries generally do not source their inputs from industries with significant direct delays, making them less affected by import shipping disruptions. In contrast, manufacturing industries such as furniture, plastics, and motor homes experience the largest total shipping delays due to their reliance on suppliers from industries with substantial direct delays.

Table 5: Direct and Indirect Shipping Delays Across Industries in Q1 2022

Industries with smallest direct delays	**Avg. ISD**	**Industries with largest direct delays**	**Avg. ISD**
Vegetable and melon farming	1.571	Ophthalmic goods manufacturing	9.541
Fruit and tree nut farming	1.709	Automotive equipment rental and leasing	9.756
Tobacco manufacturing	2.114	Computer storage device manufacturing	10.018
Paperboard mills	3.023	Home health care services	10.158
Drilling oil and gas wells	3.167	Postal service	10.580
Industries with smallest direct & indirect delays	**Avg. ISD**	**Industries with largest direct & indirect delays**	**Avg. ISD**
Gambling industries (except casino hotels)	2.297	Other furniture related product manufacturing	16.594
Junior Colleges, Colleges, Universities, and Professional Schools	2.473	Funds, trusts, and other financial vehicles	16.669
Federal general government (non-defense)	2.756	Other plastics product manufacturing	16.941
Newspaper publishers	2.772	Motor home manufacturing	17.342
Federal general government (defense)	2.923	Cheese manufacturing	18.794

Source: FactSet Shipping Data and authors' calculations.
Note: The calculation of the average ISD index per consignee excludes any shipments where the consignee is unidentified.

Fact 4: Port Diversification Is Associated with Smaller Delays. We explore the factors that can reduce shipping delays at the consignee level. During supply chain disruptions, many believe that supplier diversification—specifically, increasing the number of input suppliers—can help mitigate the impact of these disruptions by minimizing the risk of input shortages if one supplier is unable to produce. In our analysis, we observe a similar yet distinct pattern: utilizing multiple destination and origination ports is linked to shorter average shipping delays at the consignee level. This is likely due to the increased flexibility in accessing more efficient ports when others are experiencing delays.

Table 6 shows the distribution of destination and origination ports used by consignees in 2022, including both the overall sample and those in the top quartile based on shipment volume. On average, consignees utilized 2.5 destination ports and 3.28

origination ports, although there is significant variation among them, with a maximum of 33 destination ports and 131 origination ports recorded. As expected, the number of ports used correlates with shipment volume; consignees in the top quartile in terms of the number of shipments averaged 5.1 destination ports and 7.6 origination ports. Nevertheless, substantial heterogeneity in port usage remains apparent within this group.

Table 6: Number of Ports Used by Consignees in 2022

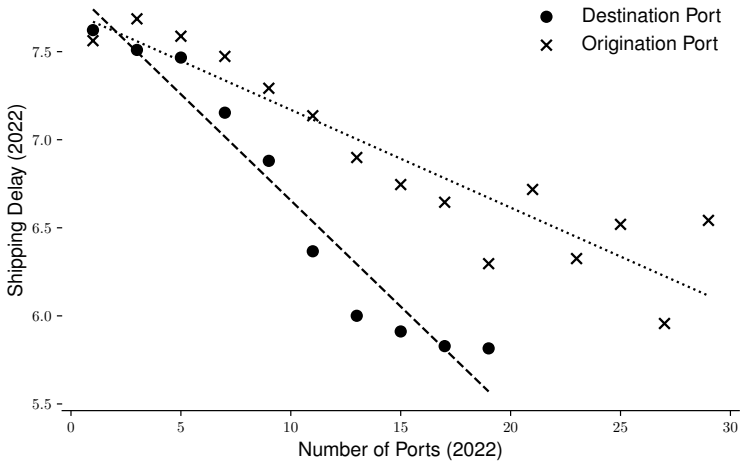
# of destination ports	**Count**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
All	44287	2.539	2.664	1.0	1.0	2.0	3.0	33.0
Top quartile ($\geq$ 22 shipments)	11163	5.168	3.991	1.0	2.0	4.0	7.0	33.0
# of origination ports	**Count**	**Mean**	**Std**	**Min**	**25%**	**50%**	**75%**	**Max**
All	44287	3.286	4.683	1.0	1.0	2.0	4.0	131.0
Top quartile ($\geq$ 22 shipments)	11163	7.649	7.532	1.0	3.0	6.0	9.0	131.0

Source: FactSet Shipping Data and authors' calculations.
Note: The calculation of the average ISD index per consignee excludes any shipments where the consignee is unidentified.

Figure 4 illustrates the relationship between port diversification and shipping delays in 2022, using a binscatter plot. Observations are first divided into equal-sized bins based on the number of destination and origination ports used by consignees in 2022, with average shipping delays calculated for each bin. The plot displays both the relationships for destination ports (circles) and origination ports (x mark). Dashed (dotted) lines represent the OLS fit for the number of destination ports (origination ports) and average shipping delays. The observed negative correlation indicates that utilizing a greater number of destination and origination ports for receiving shipments is associated with shorter shipping delays.

Table 7 offers additional insights through OLS regression analysis, controlling for firm-level factors that likely influence consignees' choice of port numbers. Columns 1 and 2 explore the relationship between the average shipping delay experienced by consignees in 2022 (Avg. ISD) and the number of destination and origination ports used (Dest. Ports and Orig. Ports, respectively). The analysis controls for variables

Figure 4: Shipping Delay vs. Number of Destination and Origination Ports



Source: FactSet Shipping Data and authors' calculations.
Note: Each dot represents the average shipping delay for consignments with a specific number of destination ports in 2022, while each x mark shows the average delay for consignments with a specific number of origination ports in the same year. The dashed line denotes the OLS regression fit for delays versus the number of destination ports, and the dotted line shows the fit for delays versus the number of origination ports.

such as the number of shipments and includes fixed effects for the industries and states of the consignees. The results indicate that having a larger number of destination and origination ports is associated with shorter shipping delays.

Utilizing multiple destination ports for imports allows consignees to mitigate the risk of failure at any single port, facilitating the rerouting of shipments through more efficient ports when others face delays. Similarly, engaging multiple origination ports lessens the risk of delays when one port or region encounters a disruption. Columns 3 and 4 of Table 7 support these observations. Column 3 shows the results of regressing the change in the share of transactions at each destination port between 2022 and 2020 (Δ Share Ports) on the change in average shipping delays at each destination port over the same period (Δ ISD Dest. Port), controlling for the number of shipments and including fixed effects for industries and states. The negative coefficient on Δ ISD Dest. Port indicates that consignees reduce their use of ports with higher delays and increase

their use of ports with shorter delays. Column 4 reveals similar results, examining the relationship between the use of origination ports and delays at those ports.

Table 7: OLS Results: Port Diversification and Shipping Delays

	Avg. ISD		**Δ Share Ports**	
	(1) Dest.	**(2) Orig.**	**(3) Dest.**	**(4) Orig.**
Dest. Ports	-0.0734			
	(0.0112)			
Orig. Ports		-0.0297		
		(0.00650)		
Δ ISD Dest. Port			-0.000888	
			(0.000207)	
Δ ISD Orig. Port				-0.000946
				(0.000171)
Observations	24637	24637	49289	57571
R^2	0.091	0.090	0.044	0.056

Source: FactSet Shipping Data and authors' calculations.
Note: Standard errors in parentheses. All regressions include industry (primary SIC codes) and state fixed effects and control for the consignee's total number of shipments.

Fact 5: More Integrated Supply Chains Are Associated with Shorter Delays. Another factor that may influence firm-level variations in average shipping delays is the structure of the supply chain, namely the degree of supply chain integration. Integration of supply chain can affect shipping delays in both positive and negative ways. On the positive side, a more integrated supply chain may be less vulnerable to delays because contracts between the shipper and consignee can be more flexible than market transactions. This flexibility allows for easier rerouting of shipments, the use of alternative ports, and better timing, which can help reduce shipping delays. Conversely, a vertically integrated supply chain can be more susceptible to delays if it is difficult to change suppliers. This inflexibility limits opportunities for supplier diversification, and thus, limits port diversification, and can exacerbate the impact of disruptions.

We assess supply chain integration by measuring the proportion of transactions between a shipper and consignee that share the same corporate ultimate parent. Specifically, we aggregate shipments to consignees' ultimate parent level, and calculate the share of transactions conducted by the ultimate parent with shippers that also have the same ultimate parent. For instance, if Ford Motor Company imports an auto part from its subsidiary, AutoAlliance Thailand, we classify this shipment as a within-firm transaction since both the shipper and consignee share the corporate ultimate parent, Ford Motor.

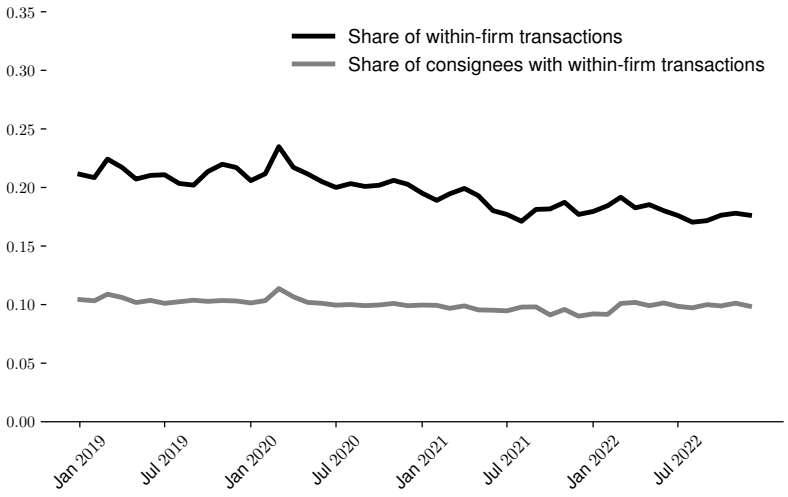
Figure 5 illustrates the time series of this metric: the black solid line represents the monthly share of within-firm shipments, while the gray solid line indicates the proportion of consignees' ultimate parents who had at least one within-firm shipment during the month. Between 2019 and 2022, nearly 20% of shipments recorded in FactSet were within-firm transactions, and 10% of consignees' ultimate parents had at least one within-firm shipment each month.[5]

Figure 6 shows the relationship between within-firm shipment shares and average shipping delays in 2022, using a binscatter plot. Observations are first divided into equal-sized bins based on within-firm shipment share for 2022, and then the average shipping delays are calculated for each bin. The plot includes both the overall sample (circles) and a subset restricted to U.S.-based ultimate parents primarily operating in the manufacturing sector (triangles). The dashed and dotted line represents the OLS fits for the overall sample and for the U.S. manufacturing sector sample, respectively.

The figure demonstrates that average shipping delays decrease as within-firm shipment share increases, with a stronger negative association observed in the sample of U.S.-based Ultimate Parents in the manufacturing sector. Table A.4 in Appendix A.3 further supports the negative association between within-firm shipment shares and av-

[5]This degree of within-firm shipments varies across different industries and countries of the ultimate parent. Table A.3 in Appendix A.3.2 lists industries and countries of the ultimate parent with the highest and lowest within-firm transaction shares.

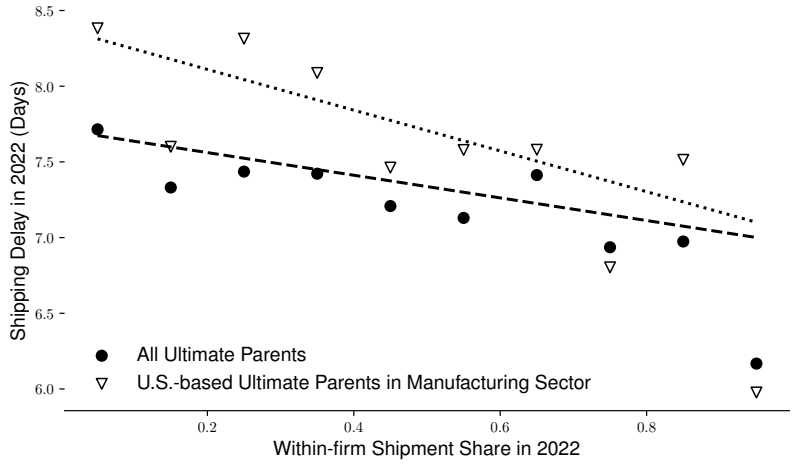
Figure 5: Monthly Share of Within-Firm Shipments and Consignees with Within-Firm Shipments



Source: FactSet Shipping Data and authors' calculations.
Note: The figure excludes data with unidentified shippers or consignees. The black solid line shows the share of transactions that are within-firm, while the gray solid line shows the share of consignees' ultimate parents who had at least one within-firm shipment during the month.

erage shipping delays through regression analysis, controlling for factors such as the number of transactions, industry, and the country of the consignees' ultimate parents.

Figure 6: Shipping Delay and Within-Firm Shipment Share



Source: FactSet Shipping Data and authors' calculations.
Note: Each dot represents the average shipping delay within an equal-sized (0.10) bin of within-firm shipment shares in 2022. Dots show raw averages, while triangles represent averages for consignees' ultimate parents located in the U.S. with primary SIC codes in the manufacturing sector (SIC codes 2000 to 3999). The dashed and dotted lines indicate the OLS regression fits for the entire sample of ultimate parents and the U.S.-based ultimate parents in the manufacturing sector, respectively.

5 Discussion and Conclusion

The origins, features and consequences of global supply chains have long been a topic of great interest to economists. Recent geopolitical shocks, natural disasters, political shifts, and public health crises have led to increased attention on how to measure the extent of supply chain disruptions and the level of resilience in overcoming them. We argue that this is fundamentally a firm-level question that needs to be investigated by exploring firm heterogeneity in response to supply chain disruptions.

In this spirit, we introduce a new measure of supply chain disruptions at the firm level, using shipping data that contains information on the expected arrival date and actual arrival date of imports. We document considerable variation across firms and industries in response to these disruptions. Our findings show that these disruptions are mitigated by greater diversity in port selection and supplier country of origin. Moreover, firms with a higher level of integration in their supply chains (i.e., a greater share of internal firm shipments) are more resilient to shocks.

While these stylized facts enhance our understanding of the impact of supply chain disruptions, several limitations remain. First, we only measure seaborne imports which excluded important supply chain relationships mediated by air and land. Firms might be using these alternative transportation methods to mitigate for disruptions or complement existing operations. Second, our measure of supply chain disruptions could be improved if we had a complete understanding of how the expected arrival date is calculated, a challenge we are aiming to solve in future work. Finally, the patterns we observe are correlations and do not suggest a set of practices firms should adopt to improve resilience.

In future work, we propose to extend this analysis in several ways. First, we plan to better understand the mechanisms driving the resilience of more integrated firms. It could be that they reduce delays due to better communication and coordination with captive suppliers; however, these advantages are likely balanced against reduced

flexibility to shift to new suppliers. Similarly, while we find that firms with partners in multiple countries are more resilient, they likely face increased coordination costs—a trade-off we will investigate in future work. We will also explore the connection between supply chain disruptions and firm performance, including sales, revenue, and inventory. Additionally, we plan to investigate how firms respond to supply chain disruptions through hiring and the creation of new roles to manage supply chains. Finally, we will explore the impact of supply chain disruptions on new business entry in affected sectors. Taken together, we aim to further develop insights into measuring supply chain disruptions and understanding how firms respond to them, providing guidance for economists to refine the concept of resilience.

References

Senay Agca, Volodymyr Babich, John R Birge, and Jing Wu. Credit shock propagation along supply chains: Evidence from the cds market. *Management Science*, 68(9):6506–6538, 2022.

Laura Alfaro and Davin Chor. Global supply chains: The looming "great reallocation". Technical report, National Bureau of Economic Research, 2023.

Xiwen Bai, Jesús Fernández-Villaverde, Yiliang Li, and Francesco Zanetti. The causal effects of global supply chain disruptions on macroeconomic outcomes: evidence and theory. 2024.

Richard Baldwin and Rebecca Freeman. Risks and global supply chains: What we know and what we need to know. *Annual Review of Economics*, 14(1):153–180, 2022.

Richard Baldwin, Rebecca Freeman, and Angelos Theodorakopoulos. Hidden exposure: measuring us supply chain reliance. Technical report, National Bureau of Economic Research, 2023.

David Baqaee and Emmanuel Farhi. Nonlinear production networks with an application to the covid-19 crisis. Technical report, National Bureau of Economic Research, 2020.

Gianluca Benigno, Julian Di Giovanni, Jan J Groen, and Adam I Noble. The gscpi: A new barometer of global supply chain pressures. *FRB of New York Staff Report*, (1017), 2022.

Bloomberg. One of world's top ports expects delays on china covid outbreak. 2021. URL https://www.bloomberg.com/news/articles/2021-05-29/china-s-yantian-port-extends-container-limits-to-curtail-covid. Accessed on September 20th, 2024.

Christoph E Boehm, Aaron Flaaen, and Nitya Pandalai-Nayar. Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tōhoku earthquake. *Review of Economics and Statistics*, 101(1):60–75, 2019.

Pablo Burriel, Iván Kataryniuk, Carlos Moreno Pérez, and Francesca Viani. A new supply bottlenecks index based on newspaper data. 2023.

Julia Cajal-Grossi, Davide Del Prete, and Rocco Macchiavello. Supply chain disruptions and sourcing strategies. *International Journal of Industrial Organization*, 90:103004, 2023.

Vasco M Carvalho, Makoto Nirei, Yukiko U Saito, and Alireza Tahbaz-Salehi. Supply chain disruptions: Evidence from the great east japan earthquake. *The Quarterly Journal of Economics*, 136(2):1255–1321, 2021.

Peter Wankuru Chacha, Benard Kipyegon Kirui, and Verena Wiedemann. Supply chains in times of crisis: Evidence from kenya's production network. *World Development*, 173:106363, 2024.

Pablo Fajgelbaum, Pinelopi Goldberg, Patrick Kennedy, Amit Khandelwal, and Daria Taglioni. The us-china trade war and global reallocations. *American Economic Review: Insights*, 6 (2):295–312, 2024.

Aaron Flaaen, Flora Haberkorn, Logan Lewis, Anderson Monken, Justin Pierce, Rosemary Rhodes, and Madeleine Yi. Bill of lading data in international trade research with an application to the covid-19 pandemic. *Review of International Economics*, 31(3):1146–1172, 2023.

Rana Foroohar. We need to know where the risks in supply chains really lie. *Financial Times*, 2024. URL https://www.ft.com/content/e8a94c4c-da26-4f09-b8cd-e1008a193615. Accessed on September 9th, 2024.

Pinelopi K Goldberg and Tristan Reed. Is the global economy deglobalizing? if so, why? and what is next? *Brookings Papers on Economic Activity*, 2023(1):347–423, 2023.

Sanjith Gopalakrishnan, Daniel Granot, Frieda Granot, Greys Sošić, and Hailong Cui. Incentives and emission responsibility allocation in supply chains. *Management Science*, 67(7): 4172–4190, 2021.

Matthew V Gordon and Todd E Clark. Supply chain disruptions and inflation. *Research [in] Brief*, (20230620), 2023.

Gene M Grossman, Elhanan Helpman, and Hugo Lhuillier. Supply chain resilience: Should policy promote international diversification or reshoring? *Journal of Political Economy*, 131 (12):3462–3496, 2023.

Gene M Grossman, Elhanan Helpman, and Alejandro Sabal. Optimal resilience in multi-tier supply chains. *The Quarterly Journal of Economics*, page qjae024, 2024.

Sebastian Heise. How did china's covid-19 shutdown affect us supply chains? Technical report, Federal Reserve Bank of New York, 2020.

Gaurav Khanna, Nicolas Morales, and Nitya Pandalai-Nayar. Supply chain resilience: Evidence from indian firms. Technical report, National Bureau of Economic Research, 2022.

Yong H Kim and Gerald F Davis. Challenges for global supply chain sustainability: Evidence from conflict minerals reports. *Academy of Management Journal*, 59(6):1896–1916, 2016.

Ernest Liu, Vladimir Smirnyagin, and Aleh Tsyvinski. Supply disruptions index (sdi): Data and methodology. *Available at SSRN 4430231*, 2023.

Greg Rosalsky. How 'chaos' in the shipping industry is choking the economy. 2021. URL https://www.npr.org/sections/money/2021/06/15/1006381735/how-chaos-in-the-shipping-industry-is-choking-the-economy#:~:text=With%20so%20much%20shipping%20capacity,to%20the%20Freightos%20Baltic%20Index. Accessed on September 19th, 2024.

Cyrille Schwellnus, Antton Haramboure, and Lea Samek. Policies to strengthen the resilience of global value chains: Empirical evidence from the covid-19 shock. 2023.

Vladimir Smirnyagin and Aleh Tsyvinski. Macroeconomic and asset pricing effects of supply chain disasters. Technical report, National Bureau of Economic Research, 2022.

White House. Executive order on america's supply chains. *Briefing Room, February*, 24, 2021a.

White House. Recent progress and actions on port congestion. 2021b. URL https://www.whitehouse.gov/briefing-room/blog/2021/11/10/recent-progress-and-actions-on-port-congestion/. Accessed on September 20th, 2024.

Di Wu. Text-based measure of supply chain risk exposure. *Management Science*, 70(7):4781–4801, 2024.

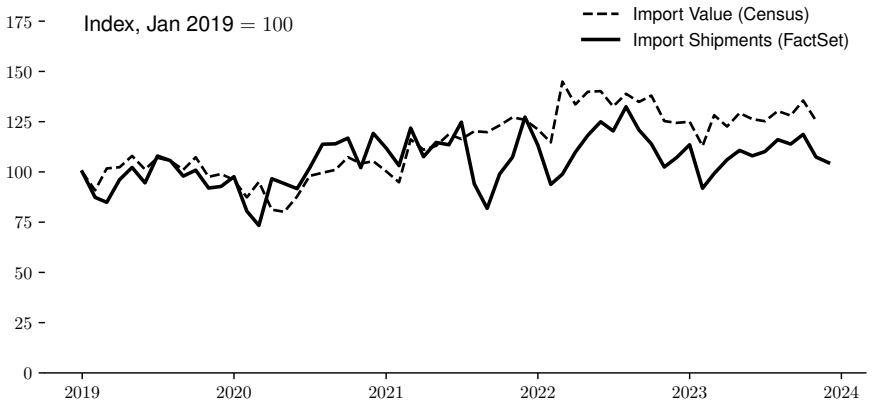
Appendix

A.1 Detail about FactSet Shipping Data

A.1.1 Data Coverage

In this section, we evaluate the accuracy of FactSet Shipping Data in reflecting actual import shipment activities in the U.S. and provide further details on the coverage of FactSet data. We start by comparing aggregated FactSet Shipping Data with U.S. Census trade aggregates. Figure A.1 illustrates two measures of trade volume: the monthly number of shipments recorded in FactSet (depicted by the black solid line) and the monthly import volume from U.S. Census data. Both metrics are normalized to a baseline of 100 for the month January 2019. This figure shows that FactSet's shipment volume closely tracks the official import volume measures over time.

Figure A.1: Comaprison with U.S. Census Monthly Import Data



Source: FactSet Shipping Data, U.S. Census Bureau, and authorsćalculations.
Note: This figure compares the monthly number of shipments from FactSet Shipping Data with monthly import values from the U.S. Census Bureau. Both metrics are normalized to their values in January 2019.

Table A.1 provides a summary of the top five U.S. destination ports and foreign origination ports based on shipment data from FactSet for the years 2019 and 2022. The Port of Los Angeles leads as the largest U.S. destination port, handling over 13 million shipments. It is followed by the Port of New York/Newark, Long Beach, Savannah, and Houston. These ports also rank as the top five in terms of import volume, according to U.S. Census Trade Data for the same period. For the geographic locations of these U.S. destination ports in 2022, refer to Figure A.2.

In terms of foreign origination ports, all top five are situated in Asia. The largest is the Port of Yantian in China, followed by the Port of Shanghai (China), Ningbo (China), Busan (South Korea), and Vung Tau (Vietnam). The locations of these foreign origination ports recorded in FactSet Shipping data for 2022 are illustrated in Figure A.3. Despite the presence of numerous ports in Europe, Asian ports dominate in transaction volume.

Next, we examine product category information. Ideally, Bills of Lading (BoL) should report product details along with the corresponding Harmonized Tariff Schedule (HTS) code. However, due to issues with verification and structure, approximately 90% of BoLs lack an HTS code. To enhance the completeness of the database, FactSet integrates metadata and

textual information from BoLs and other sources, applying natural language processing (NLP) to derive HTS codes.

Following FactSet's NLP process, 91.8% of the shipments recorded in the FactSet data have assigned HTS codes, though the level of detail varies. The most detailed HTS codes are 6-digit Harmonized System (HS) codes, followed by 4-digit tariff schedule codes. Not all HTS entries include the complete ten-digit HTS code, but every shipment with an HTS code includes at least a 2-digit HS code (i.e., HS Chapter).

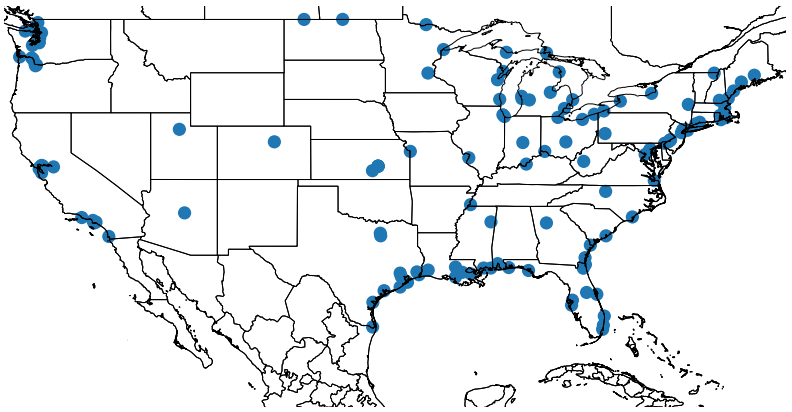
Table A.2 highlights the largest HS 2-digit product categories by shipment volume recorded in the FactSet data for 2019 and 2022. The leading category is furniture and bedding, followed by heavy manufacturing products such as nuclear reactors, plastics, vehicles, iron, and various apparel products.

Table A.1: Destination and Origination Ports with the Largest Number of Shipments

Destination Port	**# of shipments**	**Origination Port**	**# of shipments**
Los Angeles	13,267,596	Yantian (China)	8,880,944
New York/Newark	11,758,592	Shanghai (China)	8,389,110
Long Beach	11,437,397	Ningbo (China)	5,831,110
Savannah	5,268,154	Busan (Korea)	4,728,569
Houston	3,982,021	Vung Tau (Vietnam)	2,459,261

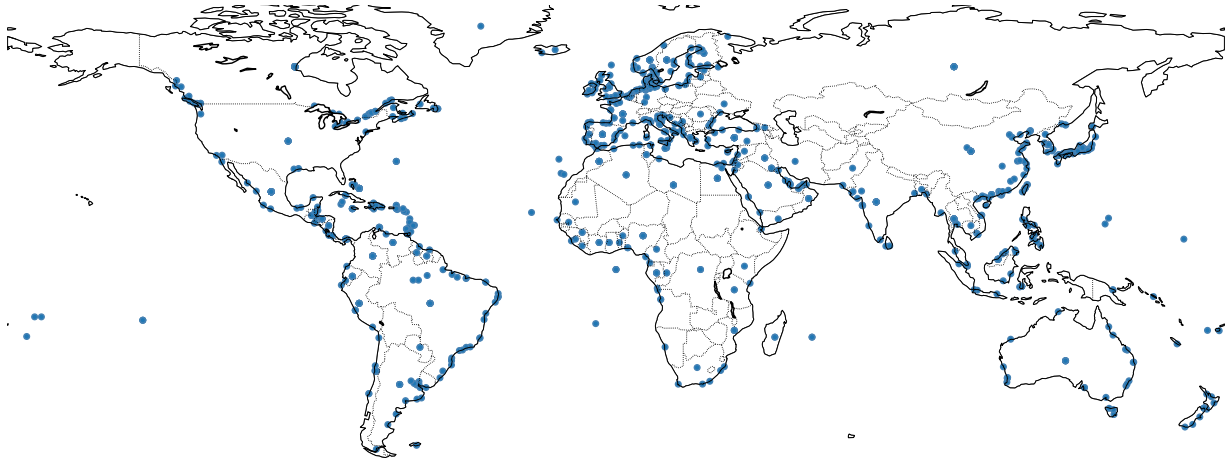
Source: FactSet Shipping Data and authors' calculations.

Figure A.2: Map of Destination Ports Recorded in FactSet Data



Source: FactSet Shipping Data.

Figure A.3: Map of Origination Ports Recorded in FactSet Data



Source: FactSet Shipping Data.

Table A.2: Product Categories with the Largest Number of Shipments

HS Chapter	HS Description	# of Shipments
94	Furniture; Bedding, Mattresses, Cushions and Similar Stuffed Furnishings; Lamps and Lighting Fittings; Prefabricated Buildings	6,819,815
84	Nuclear Reactors, Boilers, Machinery and Mechanical Appliances	5,516,238
39	Plastics and Articles Thereof	4,373,161
85	Electrical Machinery and Equipment and Parts Thereof	3,772,556
61	Articles of Apparel and Clothing Accessories, Knitted or Crocheted	3,162,472
87	Vehicles Other Than Railway or Tramway Rolling Stock, and Parts and Accessories Thereof	2,704,848
73	Articles of Iron or Steel	2,368,861
95	Toys, Games and Sports Requisites; Parts and Accessories Thereof	1,902,965
40	Rubber and Articles Thereof	1,524,366
62	Articles of Apparel and Clothing Accessories, Not Knitted or Crocheted	1,461,222

Source: FactSet Shipping Data and authors' calculations.
Note: Upon construction of the table, we exclude the shipments without any HTS codes assigned.

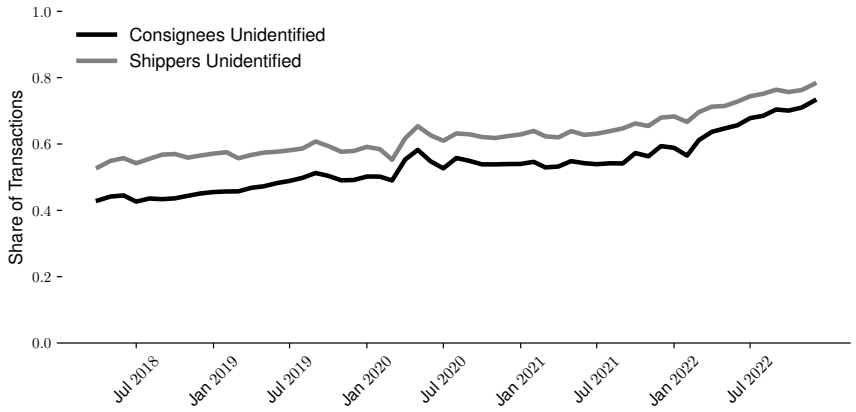
A.1.2 Firms' Redaction Activities

As outlined in Flaaen et al. (2023), companies (both consignees and shippers) can request redactions of their company information. Once a redaction request is made, it remains valid for two years before needing renewal. After this period, any transactions by the firm are no

longer redacted. Since company information is obscured in the Bill of Lading (BoL) data, data sources that extract information from BoL records, such as FactSet and Pangiva, face the issue of incomplete company information.[6]

Figure A.4 depicts the monthly proportion of shipments in the FactSet Shipping Data with consignee or shipper identities redacted. Over the sample period from 2018 to 2022, there is a gradual increase in the share of transactions with redacted identities, stabilizing at around 50%. This upward trend in redaction is consistent with findings reported in other sources (Flaaen et al. 2023).

Figure A.4: Share of Transactions with Redacted Identities



Source: FactSet Shipping Data.

Two key points should be noted. First, while redactions obscure company identities in the BoL data, other details remain unaffected. For instance, information on expected and actual arrival dates, as well as details about the destination and origination ports, are preserved even if shipper or consignee identities are redacted. Consequently, analyses that do not rely on shipper or consignee identities are not impacted by the redaction of firm information.

Second, the process of firm redaction limits the available data for analyses requiring shipper or consignee identities. Since firms can choose whether or not to redact their identities, selection bias may be a concern. However, once a firm decides to redact its information, all shipments associated with that firm are redacted uniformly, eliminating any selection bias regarding which shipments are redacted.

A.2 Other Supply Chain Disruption Indices

A.2.1 Global Supply Chain Pressure Index (GSCPI)

We compare our ISD index with the Global Supply Chain Pressure Index (GSCPI) provided by the Federal Reserve Bank of New York (Benigno et al. 2022) to highlight differences in how supply chain disruptions are measured. The GSCPI incorporates data on cross-border shipping costs, including the Baltic Dry Index and the HARPEX Index, as well as airfreight cost indices

[6]Some data sources, like Panjiva, attempt to infer redacted identities by matching firm names with historical shipment patterns. However, this approach can lead to inaccuracies and mismatches, as discussed in Smirnyagin and Tsyvinski (2022).

from the U.S. Bureau of Labor Statistics. Additionally, it includes Purchasing Managers' Index (PMI) surveys, which track inventory levels and order backlogs.

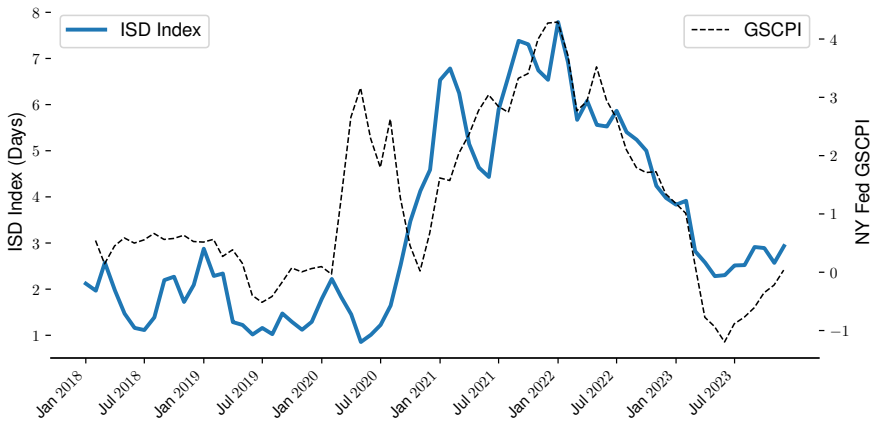
The GSCPI primarily measures the cost variations associated with supply chain disruptions, reflecting overall fluctuations in supply and demand, as noted in Bai et al. (2024). Moreover, the PMI surveys capture both shipping and production delays through product delivery delays.

Figure A.5 illustrates the time series plots for the ISD Index and GSCPI. Before 2020, both indices exhibited stable trends. However, with the onset of the COVID-19 pandemic in mid-2020, the GSCPI experienced a significant increase and remained elevated. From late 2020 onward, both indices displayed a parallel upward trend until January 2022.

The divergence between the two indices during the first half of 2020 likely stems from two main factors. First, the GSCPI is affected by transportation demand and supply. In the early months of 2020, transportation demand exceeded supply, leading to higher transportation costs. Second, the GSCPI also reflects delays in product delivery due to production disruptions, which the ISD Index does not account for. During this period, production facility shutdowns in various regions, such as China, caused notable production delays. Despite these delays in production, our ISD Index indicates that shipping was not significantly delayed during this time, given the products being shipped.

The ISD Index captures several aspects of supply chain disruptions that the GSCPI does not. First, the ISD Index accounts for variations at the firm and shipment levels, while the GSCPI is measured at the industry level. Second, the ISD Index specifically tracks shipping delays for products that are already in transit, whereas the GSCPI encompasses any delays in product delivery. Lastly, while the GSCPI is affected by transportation demand, which reflects firms' endogenous decisions, the ISD Index focuses on shipping delays that are beyond firms' control or prediction.

Figure A.5: Comparison between the ISD Index and GSCPI



Source: FactSet Shipping Data, Federal Reserve Bank of New York, and authors' calculations.
Note: The figure shows the monthly averages of the ISD Index and GSCPI. The left y-axis represents the number of days for the ISD Index, while the right y-axis represents the GSCPI values. The x-axis denotes the months.

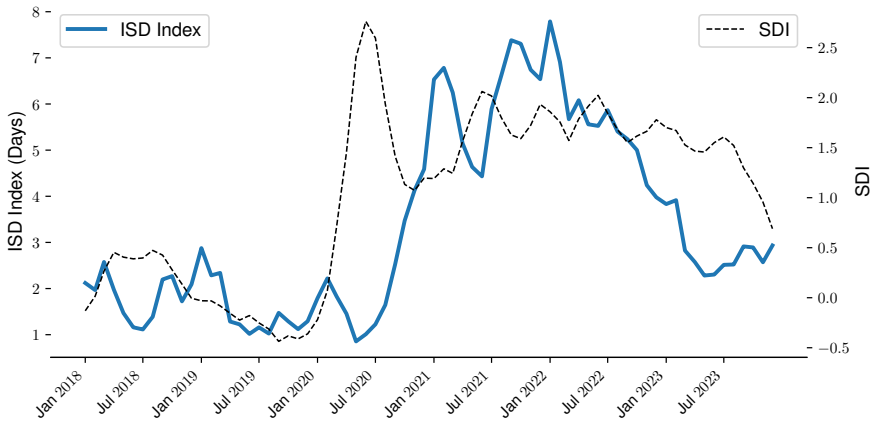
A.2.2 Supply Disruptions Index (SDI)

We next compare our ISD Index with the Supply Chain Disruption Index (SDI) developed by Smirnyagin and Tsyvinski (2022).[7] Like the FactSet Shipping Data, Smirnyagin and Tsyvinski (2022) uses the S&P Global Panjiva dataset, which includes scraped Bill of Lading (BoL) information. Their approach identifies supply chain disruptions by monitoring regular consignee-shipper relationships and defining a disruption as the transition of an active relationship to an inactive one. The SDI Index thus captures supplier-buyer relationship aspect of supply chain disruptions.

Figure A.6 compares our ISD Index with SDI. Before 2020, both indices exhibited stable trends. The SDI sharply increases in the mid-2020, while the increase in ISD Index starts in early 2021. Both indices remain high until mid 2022 until the ISD Index starts decreasing in after mid 2022.

The discrepancies between the two indices arise from three main differences. First, while both the SDI and ISD Index can vary at the firm level, the SDI Index is binary, taking only values of zero or one (indicating whether the consignee-shipper relationship becomes inactive or remains active). In contrast, the ISD Index is continuous and reflects the magnitude of shipping delays. Second, the SDI Index may capture delays in shippers' production, whereas the ISD Index specifically measures shipping delays given that the products are already produced. Finally, the SDI Index reflects the decisions of consignees and shippers regarding whether to complete a transaction or maintain an existing supplier-buyer relationship, while the ISD Index captures more exogenous variations in shipping disruptions, assuming that transactions between consignees and shippers are already in place.

Figure A.6: Comparison between the ISD Index and SDI



Source: FactSet Shipping Data, SDI data given by Smirnyagin and Tsyvinski (2022), and authors' calculations.
Note: The figure shows the monthly averages of the ISD Index and SDI. The left y-axis represents the number of days for the ISD Index, while the right y-axis represents the SDI values. The x-axis denotes the months.

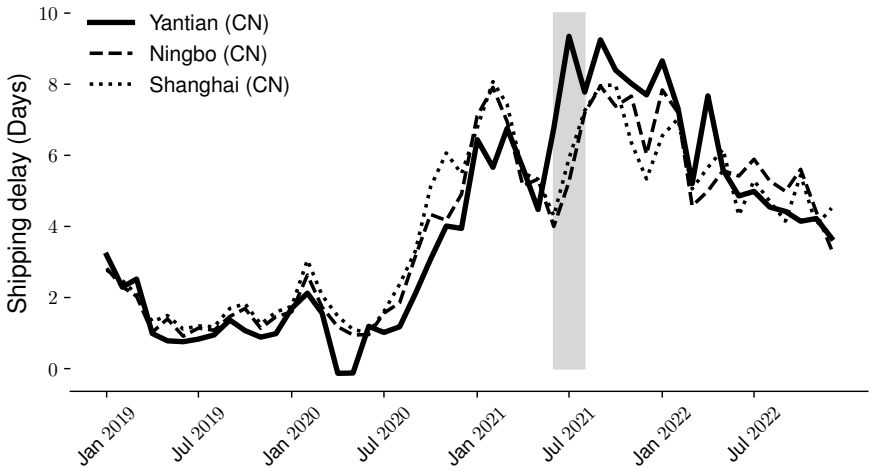
[7] Liu et al. (2023) provides technical details on the construction of the SDI Index.

A.3 Supplementary Results

A.3.1 Examples of Delays in Port Operations

Fact 1 in Section 4 indicates that the primary sources of import shipping delays often arise from operations at both origination and destination ports. Figure A.7 illustrates the monthly average ISD Index for the top three Chinese origination ports. As expected, the values for these ports are closely correlated over time. In early 2020, as the pandemic began in China, the index for all three ports experienced a sharp increase, which slightly declined after the first wave subsided around April 2021. By May 2021, while shipping delays at the ports of Ningbo and Shanghai remained low, Yantian port saw a significant rise in delays, peaking at 9.5 days (highlighted in light gray shade). This surge coincided with Yantian port's heightened COVID-19 testing protocols following an outbreak among workers, leading to a temporary suspension of container departures for export (Bloomberg, 2021). This example highlights how operations at origination ports can lead to unexpected shipping delays for shipments to the U.S.

Figure A.7: Timeseries of Average Shipping Delays at Top Three Origination Ports



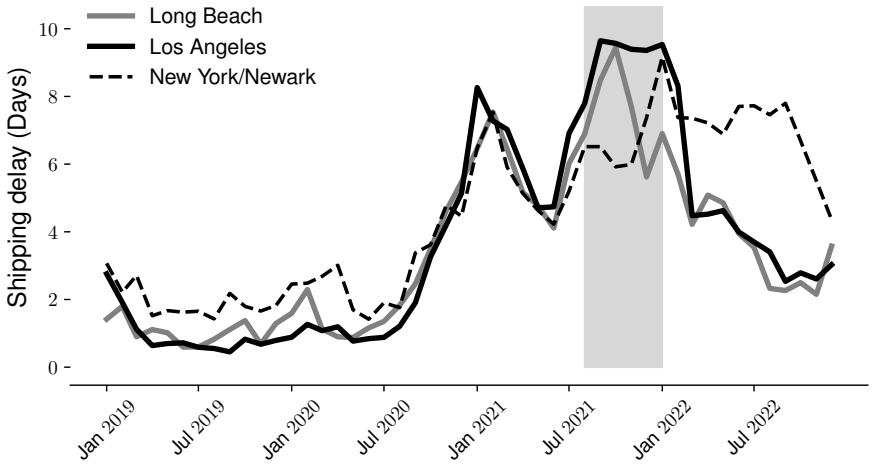
Source: FactSet Shipping Data and authors' calculations.
Note: The figure shows the monthly averages of the ISD Index for the shipments received at the ports of Yantian, Ningbo, and Shanghai in China.

Figure A.8 illustrates how unexpected shipping delays can arise from operations at destination ports in the U.S. The figure presents the monthly average ISD Index for the top three U.S. destination ports: Los Angeles, Long Beach, and New York/Newark. While the average ISD Index for these ports generally shows a correlation over time, a notable discrepancy in delays emerged during the second wave of COVID-19 from mid to late 2021. Specifically, west coast ports (Long Beach and Los Angeles) experienced significantly higher delays compared to the east coast port of New York/Newark. This difference can be attributed to severe unexpected congestion at the west coast ports, as reported in White House (2021b). This example underscores how increased congestion at destination ports can lead to unexpected shipping delays.

A.3.2 Within-firm Shipments and Shipping Delays

The degree of within-firm shipments varies across different industries and countries of the ultimate parent. Table A.3 presents the top five industries and countries by within-firm shipment

Figure A.8: Timeseries of Average Shipping Delays at Top Three Destination Ports



Source: FactSet Shipping Data and authors' calculations.
Note: The figure shows the monthly averages of the ISD Index for the shipments received at the ports of Long Beach, Los Angeles, and New York/Newark.

shares for 2022. On average, the share of within-firm shipments across industries is 10.96%, with the top five industries having shares ranging from 51% to 71%. Similarly, the average share of within-firm shipments across consignees' ultimate parent countries is 23.56%, while the top five countries have within-firm shipment shares exceeding 57%.

Table A.3: Industries and Countries with High Within-Firm Shipment Shares in 2022

Ultimate Parents' SIC Classification	**Within-Firm Shipment Share**
Manufacturers of Paper Industries Machinery	0.519886
Die-Cut Paper, Paperboard, and Cardboard	0.564706
Manufacturers of Metal Crowns and Closures	0.568317
Manufacturers of X-Ray Apparatus and Tubes, and Other Irradiation Equipment	0.600000
Manufacturers of Totalizing Fluid Meters and Counting Devices	0.710832
Ultimate Parents' Country	**Within-Firm Shipment Share**
Hong Kong	0.570277
Taiwan	0.594526
Czech Republic	0.600000
Portugal	0.652778
Japan	0.671146

Source: FactSet Shipping Data and authors' calculations.
Note: The sample is restricted to industries or countries with at least ten consignees' ultimate parents in 2022.

Table A.4 presents the results of a regression analysis where the dependent variable is the average shipping delay at the consignee's ultimate parent level, and the key independent variable is the share of within-corporation shipments. Column 1 reports results without fixed effects, Column 2 includes industry fixed effects, and Column 3 adds both industry and ultimate

corporate parent country fixed effects. The results indicate that a higher proportion of within-corporation shipments is associated with shorter shipping delays, even after accounting for variations in supply chain integration across industries and countries. This suggests that more integrated supply chains generally experience fewer delays.

Table A.4: OLS Results: Within-Company Shipments and Shipping Delays

	Avg. ISD		
	(1)	**(2)**	**(3)**
Within Shipments	-0.687	-0.722	-0.429
	(0.0975)	(0.101)	(0.153)
Industry FE	No	Yes	Yes
Country FE	No	No	Yes
Observations	35043	30542	21381
R^2	0.091	0.090	0.044

Source: FactSet Shipping Data and authors' calculations.
Note: Standard errors in parentheses. All regressions control for the total number of shipments for the consignees' ultimate parents.